TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D, C.			Madison, Wis.			Lincoln, Nebr.			Santa Fe, N. Mex.		
Dates.	a. m.	p. m.	Dates.	a. m.	p. m.	Dates.	a. m.	p. m.	Dates.	a. m.	p. m.
1918.	*mm.*	*mm.*	1918.	*mm.*	*mm.*	1918.	*mm.*	*mm.*	1918.	*mm.*	*mm.*
Aug. 12	19.89	21.28	Aug. 6	14.10	15.11	Aug. 12	13.13	23.52	Aug. 1	7.87	9.83
14	19.23	19.89	13	16.20	16.79	13	17.37	15.11	2	7.87	7.87
15	12.68	12.68	19	11.38	10.59	26	11.38	7.29	3	7.29	6.27
16	13.13	15.11	22	17.96	19.23	29	8.48	14.10	5	6.27	7.29
21	11.38	13.61	24	15.11	12.24	31	7.04	7.57	9	10.59	7.87
23	14.60	16.20	25	13.13	13.13				10	7.87	10.59
			26	13.13	9.83				13	8.48	10.59
									15	7.87	7.87
									17	9.83	7.29
									19	5.79	6.76
									23	9.14	4.75
									26	7.29	9.83
									27	6.02	6.02
									29	7.29	10.59
									30	7.87	8.48

TABLE 3.—*Daily totals and departures of solar and sky radiation during August, 1918.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.			Departures from normal.			Excess or deficiency since first of month.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Aug. 1	480	425	651	−3	−50	115	−3	−50	115
2	467	545	627	−15	72	94	−18	22	209
3	477	573	627	−4	102	96	−22	124	305
4	314	286	663	−166	−183	135	−188	−59	440
5	542	495	614	63	28	88	−125	−31	528
6	533	588	571	56	124	48	−69	93	576
7	476	489	215	2	27	−304	−67	120	272
8	536	375	294	65	−84	−222	−2	36	50
9	463	538	306	−5	81	−206	−7	117	−156
10	296	475	574	−169	21	65	−176	138	−91
11	383	258	415	−79	−193	−90	−255	−55	−181
12	503	552	613	44	104	111	−211	49	−70
13	440	509	431	−16	64	−67	−227	113	−137
14	503	573	287	50	130	−208	−177	243	−345
15	609	411	447	159	−29	−44	−18	214	−389
16	575	77	521	128	−361	33	110	−147	−356
17	126	121	315	−318	−314	−169	−208	−461	−525
18	84	499	520	−356	67	39	−564	−394	−486
19	525	593	525	88	163	57	−476	−231	−429
20	543	429	360	109	2	−115	−367	−229	−544
Decade departure							−191	−367	−453
21	593	365	590	162	−60	118	−205	−289	−426
22	437	532	405	9	110	−64	−196	−179	−490
23	500	243	389	75	−177	−77	−121	−356	−567
24	574	558	564	152	141	101	31	−215	−466
25	500	504	474	80	90	14	111	−125	−452
26	400	565	599	−18	154	131	93	29	−321
27	412	478	521	−4	70	66	89	99	−255
28	89	283	358	−325	−122	−95	−236	−23	−350
29	372	527	542	−40	125	92	−276	102	−258
30	422	297	142	12	−102	−306	−264	0	−564
31	338	548	614	−70	152	168	−334	152	−396
Decade departure							+33	+381	+148
Excess or deficiency since first of year: Gr.-cal.							−1,266	+938	+276
Excess or deficiency since first of year: Per cent.							−1.3	+1.0	+0.2

VOLCANIC ERUPTIONS AND SOLAR RADIATION INTENSITIES.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated: Washington, D. C., Sept. 13, 1918.]

In previous papers [1] curves have been presented showing variations in the annual mean values of solar radiation intensity at a few stations, for the period 1883–1912. These have been quoted by different writers,[2] and it now seems advisable to bring them up to date, since the last curve published ends in the midst of the depression of 1912–13, following the eruption of Katmai Volcano, Alaska, in June, 1912.

In Table 1 there is given for each station the month and year of the beginning and ending, and reference to a footnote gives the character, of the data utilized in constructing this new curve. The data for some of the stations is not complete. For example, at Simla, India, radiation measurements are rarely obtained in July or August. At Mount Weather, Va., the records were fragmentary until May, 1911, and the same is true of the early part of the records at Madison, Wis., and Santa Fe, N. Mex. The records of these two latter stations were not employed previous to 1914, except in determining the monthly normals for these stations.

TABLE 1.—*Duration and character of solar radiation intensity records.*

Year.	Montpellier, France.	Lausanne, Switzerland.	Pavlovsk, Russia.	Warsaw, Poland.	Washington, D. C.	Simla, India.	Paris, France.	Mount Weather, Va.	Madison, Wis.	Santa Fe, N. Mex.	Lincoln, Nebr.	Total number of stations.
1882	Dec.											
1883	×											1
1884	×											1
1885	×											1
1886	×											1
1887	×											1
1888	×											2
1889	×											1
1890	×											1
1891	×											2
1892	×		Sept									2
1893	×		+									1
1894	×		+									1
1895	×		+									2
1896	×	Jan.	+									3
1897	×	×	+									3
1898	×	×	+									3
1899	×	×	+									3
1900	Dec.	×	+									3
1901		×	+	Jan.								3
1902		×	+	+								3
1903		×	+	+								3
1904		Aug.	+	+								3
1905			+	+	June							3
1906			+	+	○	Oct.						4
1907			+	+	○	×	Jan.	Sept.				6
1908			+	+	○	×	+	○				6
1909			+	+	○	×	+	○				6
1910			+	+	○	×	+	○	(July)			6
1911			+	+	Aug.	×	+	○	(○)			6
1912			+	+		×	+	○	(○)	(Oct.)		5
1913			Apr.	Aug.		×	Dec.	○	(○)	(○)		5
1914					Oct.	×		Sept.	○	○		4
1915					○	Dec.			○	○	July	5
1916					○				○	○	○	4
1917					○				○	○	○	4
1918					July				July	July	July	4

×=monthly means of noon solar radiation intensities.
+=monthly maxima of solar radiation intensities.
○=monthly means of solar radiation intensities with the sun at zenith distance 60°.
(○)=data inclosed in curves employed only in completing the monthly normals of the respective stations.

For stations in the United States the monthly normal has been obtained by dividing the sum of all the radiation intensities measured in the months of a given name by the total number of measurements. For the other stations it has been necessary to take the average of the monthly means for the monthly normal.

The monthly means or the monthly maxima for each station have next been expressed as a percentage of either the monthly normal or the average monthly values, and the mean of the percentages for all the stations determined for each month. These monthly means have been smoothed by the formula $\frac{a+2b+c}{4}$, where b is the mean for the month in question, and a and c are the means for the preceding and following months, respectively.

[1] *Kimball, Herbert H.* Bulletin of the Mount Weather Observatory, 3:111; 5:301.
[2] *Humphreys, W. J.* Volcanic dust and other factors in the production of climatic changes, and their possible relation to the ice ages. Bulletin of the Mount Weather Observatory, 6:1–34.
Abbot, C. G., & Fowle, F. E. Volcanoes and climate. Annals of the Astrophysical Observatory of the Smithsonian Institution, 3:211–229.

The smoothed percentages thus obtained have been plotted as dots on figure 1.

Reference to Table 1 shows that for the period December, 1882–August, 1892, data were available for a single station only, and from September, 1892, to December, 1895, from two stations only. In consequence the monthly values are much more scattering previous to 1896, and especially previous to 1893, than subsequent to these years.

Furthermore, all the radiation measurements previous to 1905 were made at noon only. It follows from the Bouguer equation [3] that the percentage of depletion due to diminished transmissibility of the atmosphere, or the percentage increase due to increased atmospheric transmission, would be greater during the winter months, when the sun's zenithal distance is at a maximum, than in the summer months, when it is at a minimum. There is evidence of this annual variation in the radiation intensities, particularly in the early part of the curve.

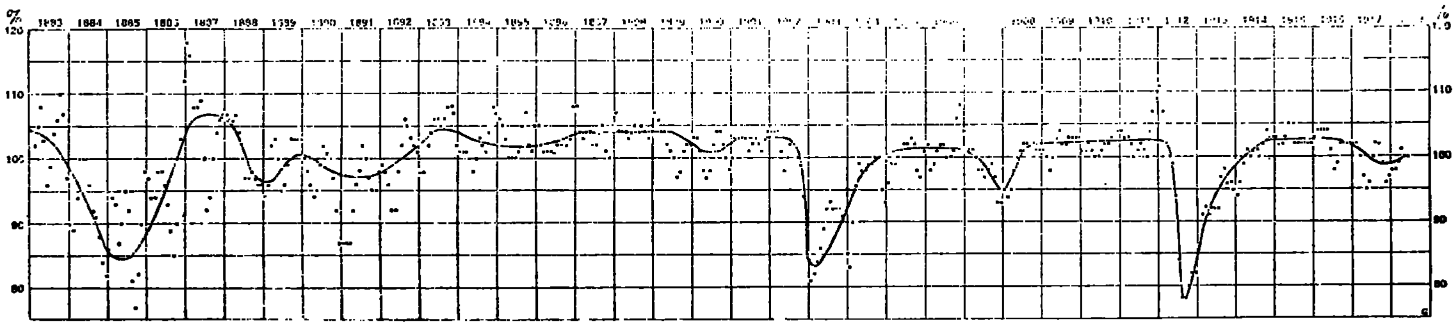

Fig. 1.—Monthly averages of solar radiation intensity at earth's surface, expressed as percentages of the monthly normals.

This has been taken into account in drawing a free-hand curve through the plotted values.

As previously shown,[4] the three great depressions in the curve of figure 1 follow the great eruptions of Krakatoa in the summer of 1883; of Pelée, Santa Maria, and Colima, in 1902, and of Katmai in June, 1912. In each case there has been complete recovery—in the case of Krakatoa, after 34 months, of Pelée after 17 months, and of Katmai, after 21 months. There are minor depressions in 1888–89 and in 1907–8 that have not been accounted for definitely, and also one in 1916–17 that may be due to the fact that since the outbreak of the European war it has been necessary to substitute data from stations in the United States for that previously obtained from stations in Europe. In consequence, the data are not so representative of conditions in the Northern Hemisphere as a whole, but are more influenced by local atmospheric conditions. Aside from the depressions noted, the smoothed monthly radiation intensities show remarkably uniform values. It is because the values obtained during the great depressions have been included in the means that the intensities measured under normal conditions generally fall between 102 and 104 per cent.

The following are the sources of the solar radiation data that have been utilized:

Montpellier, France. Eon, L. J. Intensités calorifiques de la radiation solaire et durée de l'insolation a Montpellier. (Année 1900 et résumé de la série 1883–1900.) (*In* Bulletin météorologique du Départment de l'Hérault, année 1900. Montpellier. 1901.)

Lausanne, Switzerland. **Bührer, C. & Dufour, Henri.** Résumé des observations actinométriques de l'année 1903. (Arch. sci. phys. nat., Genève. 4 pér. Tome 19. 1905. p. 388–390.) **Dufour, Henri.** L'insolation en Suisse. 1 partie. (Arch. sci. phys. nat., Genève. 4 pér. Tome 16. 1903. p. 417–434.) **Dufour, Henri & Bührer, C.** L'insolation en Suisse. 2 partie. (Arch. sci. phys. nat., Genève. 4 pér. Tome 16. p. 526–540.)

Pavlovsk, Russia. **Savinov, S. I.** [The maximum of solar radiation at Pavlovsk since 1892. The decrease in the intensity during the second half of 1912]. [Russian.] Bull., Ac. Imp. des. sci., St. Pétersbourg, 6 me sér., 1913, No. 12, p. 707–720.

Warsaw, Poland. **Gorczynski, Ladislav.** Valeurs pyrhéliométriques et les sommes d'insolation à Varsovie pendant la période 1901–1913. Varsovie, 1914.

Washington, D. C. Bulletin of the Mount Weather Observatory, 3:85–96; 5:182, 302, 303; Monthly Weather Review, 1914, 42:648; 1915, 43:112. [Monthly thereafter.]

Simla, India. Indian Monthly weather review, 1906–15.

Paris (Parc St. Maur), France. La Nature (Paris), Supplément, années 35–42, 1907–1914.

Mount Weather, Va. Bulletin of the Mount Weather Observatory, 5:303–311; 6:215–219. Monthly Weather Review, 1914, 42:139, 310, 520.

Madison, Wis. Bulletin of the Mount Weather Observatory, 5:173–183. Monthly Weather Review, 1916, 44:3, 9–12. [Monthly thereafter.]

Santa Fe, N. Mex. Monthly Weather Review, 1915, 43:439–443, 591. [Monthly thereafter.]

Lincoln, Nebr. Monthly Weather Review, 1916, 44:4–8. [Monthly thereafter.]

[3] $I = I_0 a^m$, where I_0 is the radiation intensity outside the atmosphere, a is the transmission coefficient of the atmosphere, or the proportional part of the radiation transmitted when the sun is in the zenith, m is the length of the path of the sun's rays through the atmosphere in terms of the length of the path for zenithal sun, and I is the solar radiation intensity measured at the surface of the earth. This equation is strictly true for homogeneous rays only.

[4] *Kimball, H. H.* loc. cit. *Humphreys W. J.* loc. cit.